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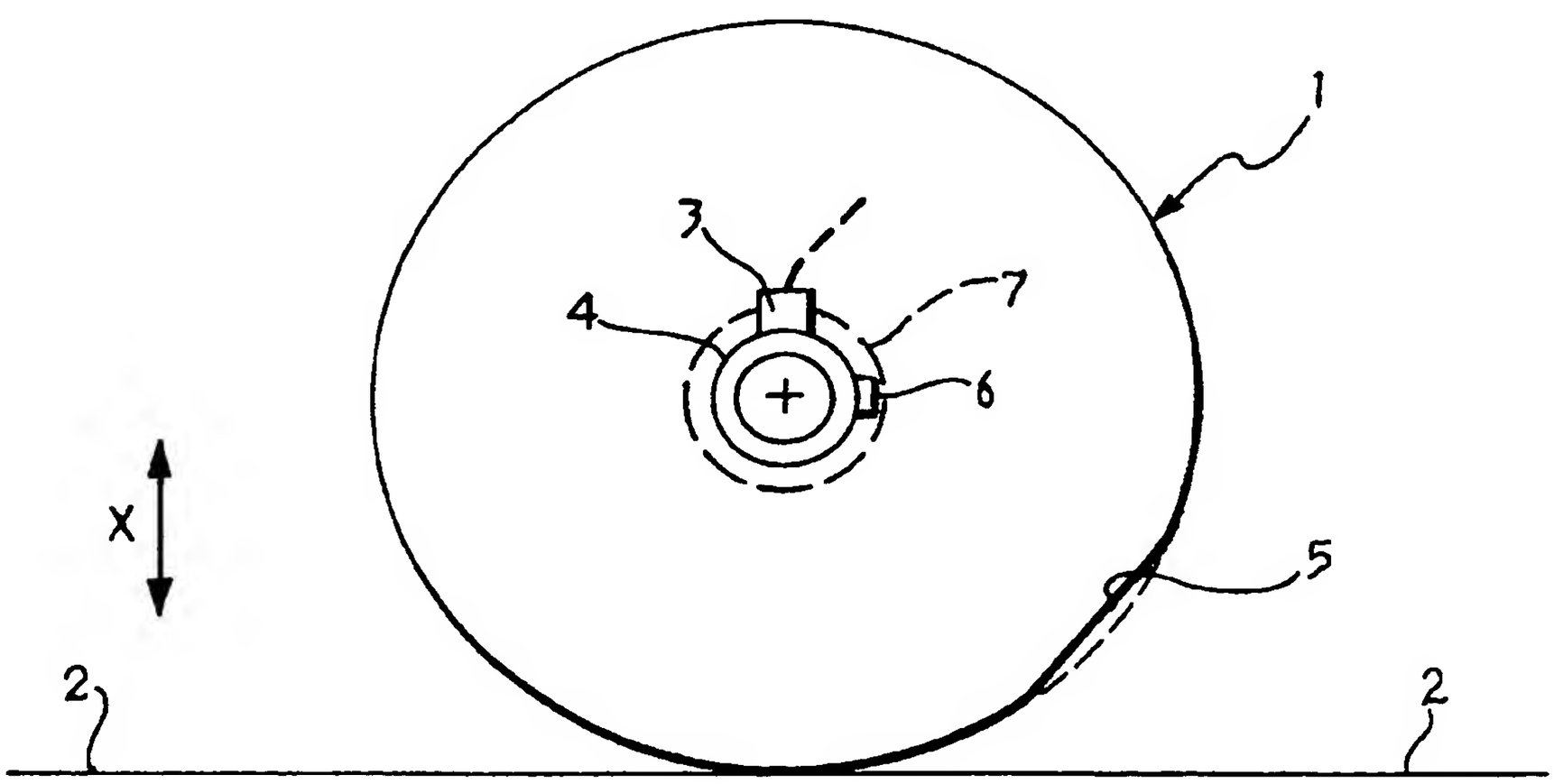
(54) Title: METHOD AND APPARATUS FOR DETECTING ROUNDNESS DEFECTS IN A RAILWAY VEHICLE WHEEL



(57) Abstract: A motion sensor (3) is associated with a wheel (1) of a railway vehicle for generating a signal (M) indicative of the motion of the wheel along a vertical axis (x). A rotation sensor (6) provides a signal (S) indicative of the rotational speed of the wheel (1). The motion (M) and rotational speed (S) signals are received by an electronic processing unit (E) which correlates these signals using the speed signal (S) to divide the vertical motion signal (M) in subsequent time portions or frames, each corresponding to a complete rotation of the wheel. A mean of the subsequent time portions of the motion signal stored over a period of time is calculated to identify actual or incipient roundness defects of the wheel.

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Method and apparatus for detecting roundness defects in a railway vehicle wheel

The present invention refers to a method and an apparatus for detecting roundness defects in a railway vehicle wheel.

The main roundness defects of the rolling surface of a wheel can be summarised as follows:
- presence of a flat in the rolling surface of the wheel on the rail, due to the wheel being locked while the railway vehicle is travelling or, more generally, due to defective operation of a brake;
- uneven wear of the wheel, owing to non-homogeneity of the material forming the wheel, which wears assuming a profile of a shape different from circular, for example oval or lobe-shaped.

It is known that a non-round wheel provokes vibration which, besides adversely affecting the operational performance of the axle, can cause damage to other parts of the vehicle and reduce the safety thereof with time.

Heretofore, methods of checking the conditions of a wheel have been limited to periodical controls, on occasion of which an expert is charged with travelling on the vehicle to assess its degree of comfort. Depending on circumstances, the expert points out that probably at least one of the eight wheels of the vehicle needs to be replaced or to be subjected to a maintenance intervention in which the wheel is turned to render its profile round.

It will be understood that this way of proceeding does not allow to predict or detect the occurrence of roundness defects in time so as to intervene before the damage gets worse.

U.S. Patent No. 5,433,111 discloses an apparatus for detecting defective conditions associated with a set of railway vehicle wheels and with a railtrack upon which a given railway vehicle travels. The apparatus comprises measurement means for generating data indicative of rotational rate of the wheels, a set of accelerometers adapted to generate data indicative of motion along three orthogonal axes, wherein one of the axes is generally vertical with respect to the railtrack, and a data processor adapted to detect, based on the received rotational rate and motion data, a defective condition associated with at least one wheel of the vehicle.

These known systems have a limit in that they do not allow to distinguish whether anomalous vibration is due to the wheels, or the axle bearings, or the railtrack or still other causes. Furthermore, the above mentioned prior art does not allow to identify in a railway vehicle which wheel or wheels are affected by defects.

It is an object of present invention to predict and/or identify in time and give a warning in real time of the occurrence of a roundness defect, of the kind of defect and its precise location, in particular distinguishing which wheel of the vehicle or train is affected by the defect.

Another object of the present invention is to provide a continuos monitoring of the operating condition of the wheel to obtain real time information concerning the variation of the defect in time so that it is possible to intervene with urgency for severe failures, or delay intervention depending on the gravity of the detected failure, or still consider the opportunity of not intervening, for example when an operation defect is stabilised or stabilising.

Another object of the invention is to optimise maintenance, so as to intervene only when it is appropriate or necessary, thereby reducing overall maintenance down time.

These and other objects, which will be better understood herein after, are achieved according to a first aspect of the present invention by a method as defined in claim 1.

According to another aspect of the invention, there is provided an apparatus as defined in claim 9.

Further important features are defined in the dependent claims.

The characteristics and advantages of the invention will become apparent from the detailed description of an embodiment thereof with reference to the appended drawings, provided purely by way of non-limiting the example, in which:
- figure 1 is a view schematically showing a wheel of railway vehicle associated with an apparatus according to the present invention;
- figure 2 is a block diagram showing the generation and processing of signals in an apparatus according to the invention;
- figure 3 shows a series of subsequent frames of a signal indicative of vertical movement of the wheel of figure 1 in the time domain; and
- figure 4 shows a signal obtained as a mean of the subsequent frames of figure 3.

Referring initially to figure 1, numeral 1 schematically designates a wheel of a railway vehicle travelling on a railtrack 2. A motion sensor 3, adapted to detect acceleration in a vertical direction x, is mounted on a

stationary support element 4 secured to or integral with an element supporting the wheel axle.

The elements shown in figure 1 are per se known to those skilled in the art and will not therefore be described in detail in the present description. For example, the stationary support element 4 may be the axle box of the bearing, or the outer cover of the axle box, or the outer stationary race of the axle bearing, or still a sealing insert mounted on said outer race.

The motion sensor 3 preferably includes a piezoelectric accelerometer of known kind associated with an amplifier incorporated in the same body containing the accelerometer.

In figure 1 there is shown an example where the rolling circumference of the wheel has a flat 5, such that when the wheel turns and passes over the flat it is subjected to a vertical acceleration that is detected by the motion sensor 3; the latter, as a consequence, generates a signal indicative of the motion of the wheel 1 along the vertical axis x.

Preferably, the signal of vertical motion is filtered through hardware and/or software filtering means for eliminating from the signal all the vibration components that are irrelevant and reducing the harmonic content of the signal only to those phenomena that are to be kept under control, i.e. vibration generated by the rolling of the wheel with a non-round profile.

The wheel is equipped with a speed sensor 6 associated with an encoder 7 fast for rotation with the axle, for example an impulse wheel of the kind normally used for detecting rotational speed. The speed sensor 6 is mounted on a

stationary support element, preferably secured to or integral with a supporting element of the wheel axle.

The constructional and operational features of speed sensors and of the relative encoders or impulse wheels (that may be of any known kind) are not relevant in themselves for the understanding of the invention and will not therefore be described in detail herein. It is sufficient here to say that, when the wheel 1 turns, it rotates fast with the encoder 7, whereby the speed sensor 6 under the influence of the encoder provides a signal indicative of the rotational speed of the wheel, generally a signal with frequency proportional to the angular speed of the wheel.

In figure 1 for simplicity there is illustrated an example in which the speed sensor 6 is mounted on the same element 4 supporting the motion sensor 3. It is evident that the choice of mounting the sensors 3 and 6 on a common supporting element may constitute a preferable solution in certain situations of use, but is certainly not an essential feature for the purposes of the implementation of the invention.

In a preferred embodiment, the speed sensor 6 is fitted to the stationary outer race of bearing.

According to a first embodiment, the encoder 7 has an irregularity, for example a longer tooth or a missing dent, which serves as a reference point of a certain angular position of the wheel and corresponds to a point on the circumference of the wheel. In this case the speed sensor 6 will provide a single pulse or signal at every complete revolution of the wheel.

As an alternative, and in accordance with a preferred embodiment, an impulse wheel having a certain number n (for

examlpe n = 80) sectors is used as an encoder, whereby the speed sensor associated with the impulse wheel will emit n impulses at each complete revolution of the wheel. The pulses generated by the speed sensor are supplied to a divider by n the output of which provides a pulse for every n pulses received by the speed sensor.

In either case, the output speed pulse S or signal supplied at each complete revolution of the wheel is supplied to an electronic processing unit E (figure 2) that receives also the signal M from the vertical motion sensor 3.

The electronic processing unit E correlates two signals M, S using the rotational speed signal or pulse S of the wheel to divide the vertical motion signal M in subsequent time portions or frames, each of which corresponds to a complete revolution of the wheel.

The frames are stored in the electronic processing unit E, or in another electronic apparatus connected thereto, forming a plurality of frames such as those represented superimposed in figure 3, where the vertical acceleration to which the wheel is subjected during a complete revolution are reproduced in ordinate. This data collection is carried out continuously over a certain period of time.

It is important to notice that when the wheel passes over a local unevenness of the railtrack, for example a discontinuity at the junction of rails, or points or a foreign body on the rail, an anomalous signal of vertical motion is generated. As a result, a corresponding anomalous frame is obtained, with evident differences with respect to the other frames, which are instead similar, if not practically identical one another.

Therefore it is possible to calculate periodically, for example every 50 frames or anyway at chosen intervals, a correlation function or index between al the frames obtained in that interval, and disregard those frames having a correlation value low than a preset value, i.e. considerably different from the others.

By calculating a mean of the remaining frames, i.e. the similar ones, there is obtained a mean waveform (figure 4) which contains only information concerning roundness defects of the wheel and which is instead free of all non-repetitive events which are due to other causes, for example irregularities of the railtrack.

As the only synchronised frequency is that of the complete revolution of the wheel, the final mean not only does not take into account forces due to causes foreign to the wheel, but neither other forces due to possible irregularities of other rotating parts (for example the rollers of the axle bearing) having a speed different from the rotational speed of the wheel. As a matter of fact, forces due to other rotating parts have frequencies different from that of the wheel and, as they are not synchronised with the rotation of the wheel, they do not affect the final mean.

In other words, the detection of the vertical motion of the wheel, synchronised with the revolution period of the wheel renders irrelevant, in the final mean, the data detected during revolutions in which the wheel has undergone non-repetitive forces, and, more generally, any datum deriving from forces having a frequency different from that of rotation of the wheel. The data collection should obviously be carried out over a period of time sufficiently prolonged as to render anomalous frames statistically irrelevant.

As will be apparent, the method of the present invention is, in theory, independent of the speed at which the train travels. However, tests carried out by the Applicant show that better results can be achieved when the train travels at a substantially constant speed above 100 km/h. For obtaining the final average wave form (figure 4) starting from the stored frames (figure 3) many statistic algorithms may be used, for example calculating the exponential moving mean, the mean value, the mean-square deviation, etc.

The above described data collection is carried out for all the wheels of the railway vehicle, whereby it is possible to detect the occurrence of a defect or predict a condition of incipient defect and follow its development with time, also identifying which wheel is being involved.

The electronic processing unit E is arranged for automatically emitting an alarm signal A when a preset threshold value identifying a condition of actual or incipient defect is reached or exceeded.

Still in accordance with the present invention, if the speed signal or pulse is generated at a certain angular position corresponding to a precise point on the circumference of the wheel, the frames so obtained will have a starting point corresponding to that position. As a result, the average wave form of a wheel will practically represent a polar diagram of the profile of the wheel, with a precise indication of the location of the defect along the circumference.

CLAIMS

1. A method of detecting roundness defects in a wheel of a railway vehicle, comprising the steps of:

(a) providing motion sensor means (3), associated with a wheel (1) of a railway vehicle, for generating a signal (M) indicative of the motion of the wheel along an essentially vertical axis (x);

(b) providing rotation sensor means (6) for supplying a signal (S) indicative of the rotational speed of the wheel (1);

(c) receiving the motion (M) and rotational speed (S) signals by means of an electronic processing unit (E) and correlating said signals using the speed signal (S) to divide the vertical motion signal (M) in subsequent time portions or frames, each corresponding to a complete revolution of the wheel;

(d) storing said subsequent time portions of the motion signal (M);

(e) calculating a mean of the subsequent time portions of the motion signal stored in a period of time for identifying, based on said mean, actual or incipient roundness defects of the wheel.

2. The method of claim 1, wherein the mean calculated in said step (e) is calculated based on a number of subsequent time portions so as to render statistically irrelevant those time portions of the motion signal (M) containing data indicative of forces which are not repeated in time with the frequency of rotation of the wheel (1).

3. The method of claim 1, wherein said step (c) comprises the step of filtering the motion signal (M) for eliminating therefrom all vibration components not generated by the rolling of the wheel on the railtrack.

4. The method of claim 1, wherein the step (b) of generating the speed signal comprises the step of:

generating a single speed signal at every complete revolution of the wheel.

5. The method of claim 1, wherein the step (b) of generating the speed signal comprises the steps of:

generating a number (n) of pulses at every complete revolution of the wheel and

transmitting said pulses to a divider by n which emits a single output speed signal every n pulses received.

6. The method of claim 1, in which the step (c) of receiving the signals (M, S) is carried out with the vehicle travelling at a substantially constant speed.

7. The method of claim 1 wherein the step (c) of receiving the signals (M, S) is carried out with the vehicle travelling at a speed exceeding 100 km/h.

8. The method of claim 1, wherein said step (e) is followed by the step of:

automatically emitting an alarm signal (A) when the mean of the subsequent time portions reaches or exceeds a preset threshold value.

9. An apparatus for detecting roundness defects in a wheel of a railway vehicle comprising:

motion sensor means (3) associated with a wheel (1) of a railway vehicle, adapted to provide a signal (M) indicative of movement of the wheel along an essentially vertical axis (x);

rotation sensor means (6), adapted for providing a signal (S) indicative of the rotational speed of the wheel (1);

electronic processing means (E) adapted for:

- receiving the motion (M) and speed (S) signals;

- correlating said signals using the speed signal (S) to divide the vertical motion signal (M) in subsequent time portions, each of which corresponds to a complete revolution of the wheel;

- storing a plurality of subsequent time portions of the motion signal (M),

- calculating a mean of the subsequent time portions of the motion signal (M) stored in a period of time; and

- identifying, based on said mean, actual or incipient roundness defects of the wheel.

10. The apparatus of claim 9, further comprising filtering circuit means adapted for filtering the motion signal (M) for eliminating therefrom all vibration components not generated by the rolling of the wheel on the railtrack.

11. The apparatus of claim 9, further including alarm means for generating automatically an alarm signal (A) when the mean of the subsequent time portions reaches or exceeds a preset threshold value.

12. The apparatus of claim 9, wherein the motion sensor means (3) are associated with an encoder (7) adapted for generating a single speed signal at each complete revolution of the wheel.

13. The apparatus of claim 9, wherein the motion sensor means (3) are associated with an encoder (7) adapted for generating a number (n) of pulses at each complete revolution of the wheel, the apparatus further including divider by n means, operatively associated with the sensor means (3), for emitting a single output speed signal at every n received pulses.

14. The apparatus of claim 9, comprising motion sensor means (3) and speed sensor means (6) coupled to each of the wheels of a railway vehicle.

15. The apparatus of claim 9, wherein the motion sensor means (3) are mounted to an element (4) supporting the axle of the wheel (1).

FIG. 1

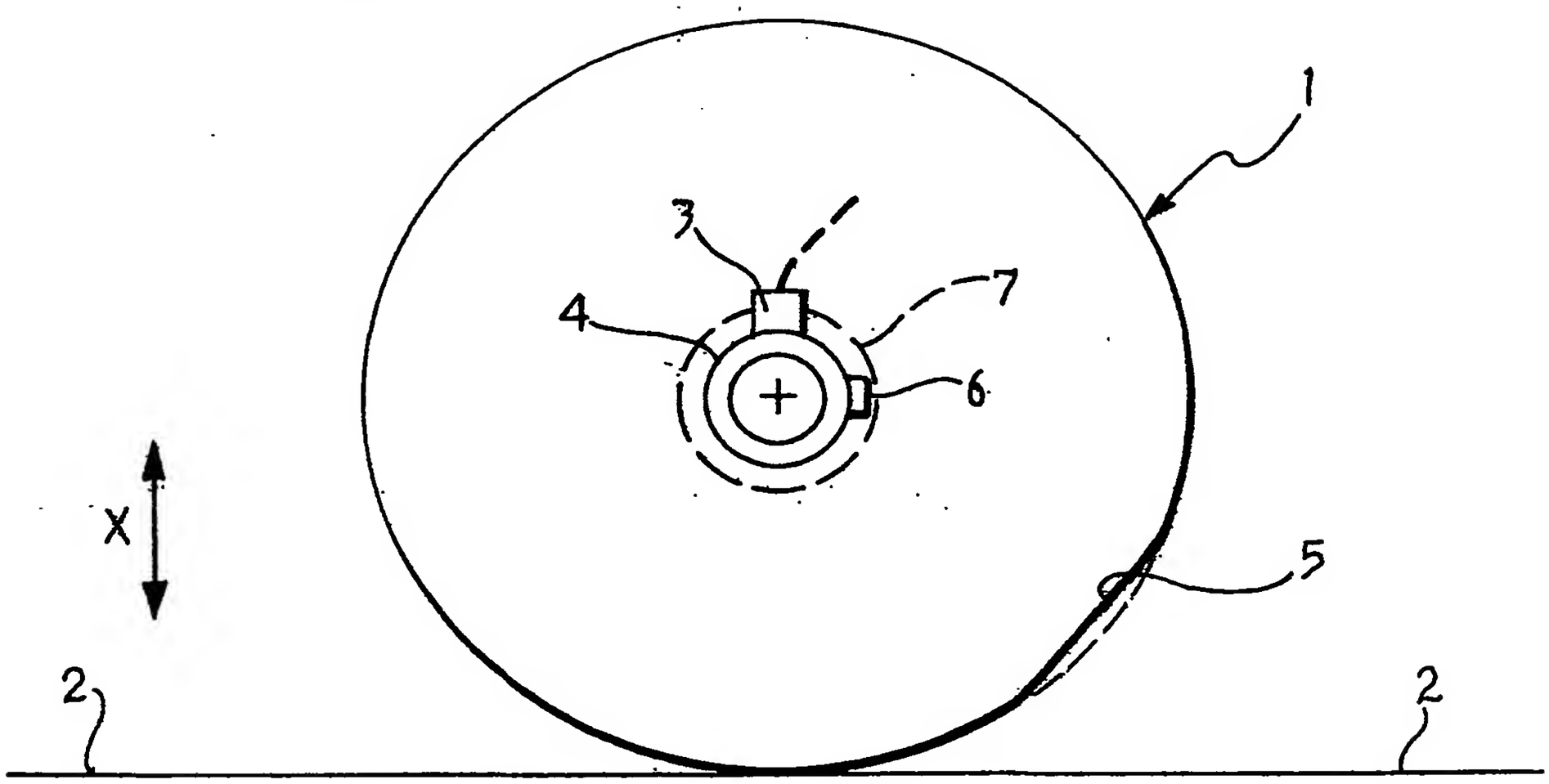
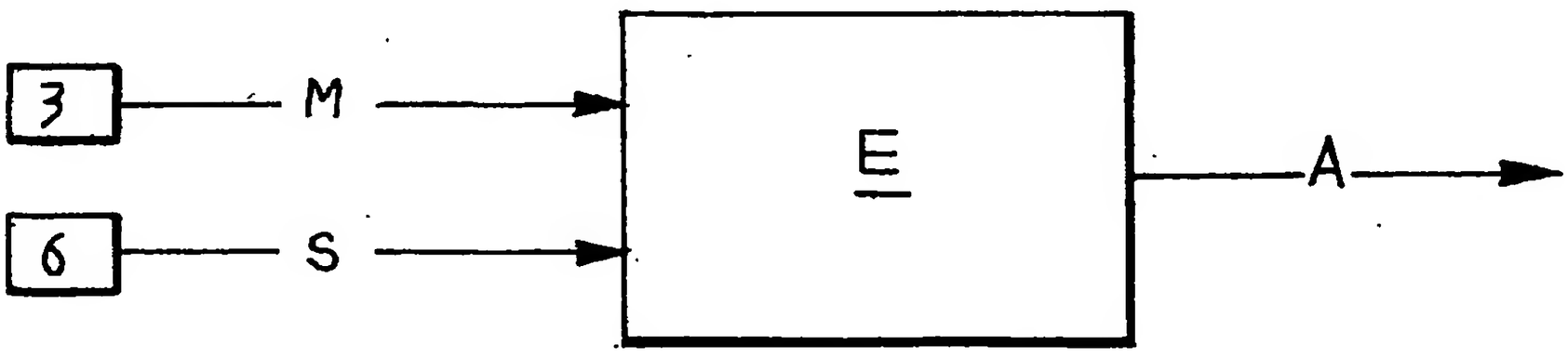


FIG. 2



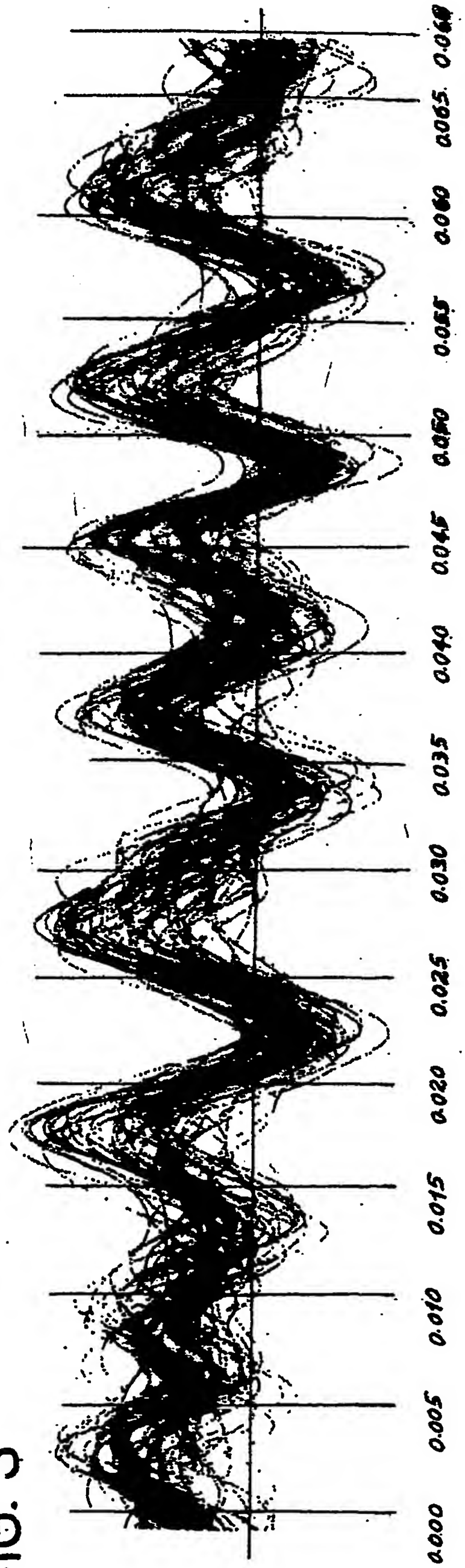

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FIG. 3

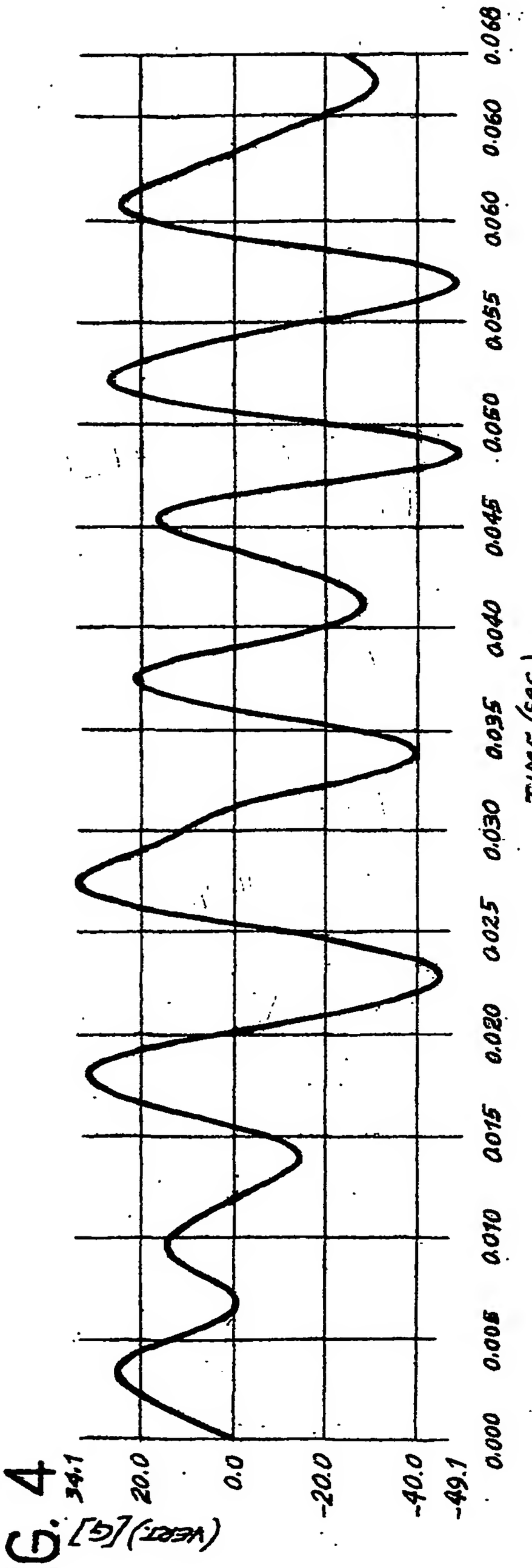
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FIG. 4

INTERNATIONAL SEARCH REPORT

Inter al Application No
PCT/EP 01/06351

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B61K9/12 G01B7/28 G01B21/20 G01M17/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B61K G01B G01M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 696 446 A (MOCHIZUKI ASAHI ET AL) 29 September 1987 (1987-09-29) column 2, line 19 -column 4, line 68; figures 1-5	1-15
A	US 5 433 111 A (HERSHEY JOHN E ET AL) 18 July 1995 (1995-07-18) column 4, line 2 -column 7, line 45; figures 1,2,3A,4A,5A,6A	1-15
A	US 3 844 513 A (BERNHARDSON R ET AL) 29 October 1974 (1974-10-29) abstract; figure 1	1-15

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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